
**State of California
The Resources Agency
Department of Water Resources**

**GROWTH INVESTIGATIONS OF WILD AND
HATCHERY STEELHEAD IN THE LOWER
FEATHER RIVER
SP-F10 TASK 3B**

**Oroville Facilities Relicensing
FERC Project No. 2100**



FEBRUARY 2004

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REPORT SUMMARY

In the summer of 2003, DWR performed an enclosure and mark recapture study in the Feather River Low Flow Channel (LFC) to assess growth, survival and movement of juvenile steelhead. Sixty juvenile steelhead were individually marked and monitored in six steel-cage enclosures placed at two LFC locations. Six hundred and thirty-one wild juvenile steelhead were also captured and individually marked through seining and electrofishing sampling.

Mark and recapture studies suggest that steelhead rearing in lower sections of the LFC grew faster than those rearing in upper sections. Furthermore, the recapture rates observed among marked steelhead confirm that many juvenile steelhead found throughout the LFC are not actively emigrating, but are more likely rearing throughout the summer months. Mark and recapture studies reveal that slightly warmer temperatures, as observed near Eye Riffle, (assuming adequate food and habitat resources) may provide better growing conditions for over-summering juvenile steelhead than upstream areas.

Results from enclosure studies showed that all fish held for greater than 30 days showed an increase in growth and condition factor (K). Growth data obtained from enclosure studies provides valuable insight into the growth of juvenile steelhead rearing in two highly different temperature regimes. Average condition factor (K) increased throughout the study period, indicating that overall physical condition was improving. However, unlike the mark-recapture study, no significant difference in growth rate was observed between upstream (Hatchery Riffle) and downstream (Eye Riffle Side Channel) sites. When compared to wild fish, steelhead reared in enclosures had only slightly lower condition factor values, an indication they were receiving appropriate amounts of food with respect to their metabolic needs (based primarily on fish size, temperature and current velocities). Additionally, except for one fish that was known to have died during the study (Eye Riffle), no steelhead showed visual signs of stress from either competition or temperature (i.e. skin lesions, fin rot, bite marks, emaciation, lethargy). On the contrary, nearly all steelhead sampled appeared satiated and energetic, and all displayed normal color.

The warmer temperature regime experienced in the lower LFC in summer 2003 is probably more suitable for steelhead growth. However, the observed temperatures are approaching the limits of steelhead tolerance ranges. Any increase in temperature (beyond that observed at Eye Riffle) would likely have deleterious effects. However, wild steelhead rearing in the lower LFC grew faster than their upstream counterparts. These fish are therefore more likely to avoid predation, smolt sooner and probably have a better chance of returning as adults. Flow regimes proposed for the LFC must consider basic physical habitat requirements and the effects that water temperature could have on the resulting growth rates of juvenile steelhead. It appears that the combination of small side channels (complex microhabitats), increased cover and appropriate water

temperatures create the most productive rearing habitat for juvenile steelhead in the lower Feather River.

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

1.1.1 Study Area

Average monthly water temperatures in the reach of the Feather River from the Fish Barrier Dam to the Thermalito Afterbay outlet range from 47°F in winter to 65°F (18.3 °C) in the summer. Water temperatures downstream of the Thermalito Afterbay outlet are generally warmer, with the maximum mean daily water temperature at the Thermalito Afterbay outlet reaching approximately 70°F (21.1 °C) in the summer. Because daily summer water temperatures often exceed 70°F below the Thermalito Afterbay outlet, it is unlikely that steelhead rear in High Flow Channel (DWR and USBR 2000). Snorkel surveys have confirmed that the area below the Thermalito Afterbay outlet harbors essentially no rearing steelhead (DWR and USBR 2000). To this end, field experiments were focused on the area above the Thermalito Afterbay Outlet, specifically the LFC (See Figure 1.1-1). Because juvenile steelhead rear in the river year round and are expected to be in the river during months when increased water temperatures are probable, field experiments were conducted in June, July and August.

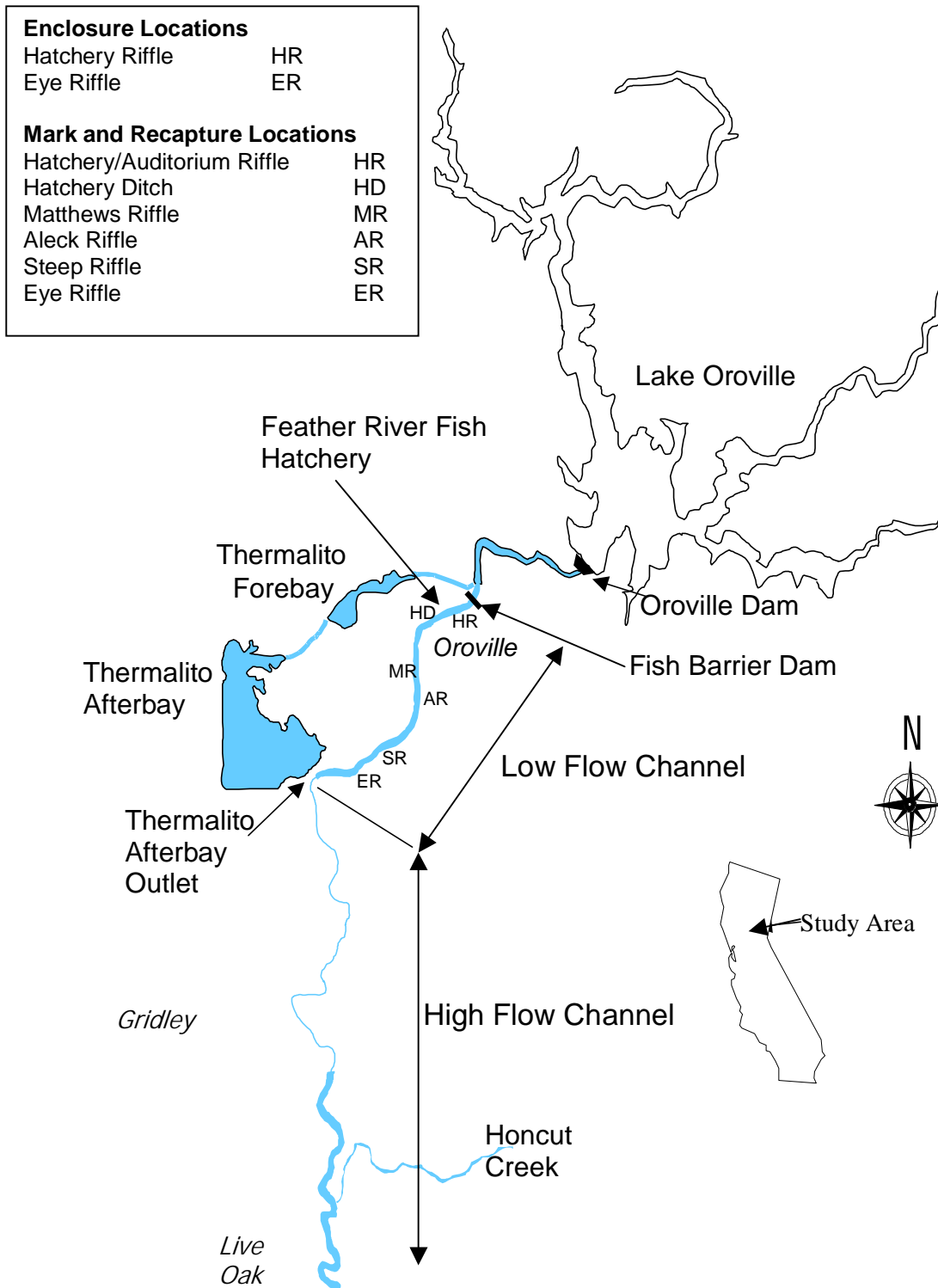


Figure 1.1-1. Lower Feather River Study Area

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet (maf) capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second (cfs) of water into the river.

The Power Canal is a 10,000-foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The

Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate 15,000 to 20,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. California Department of Fish and Game's (DFG) habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

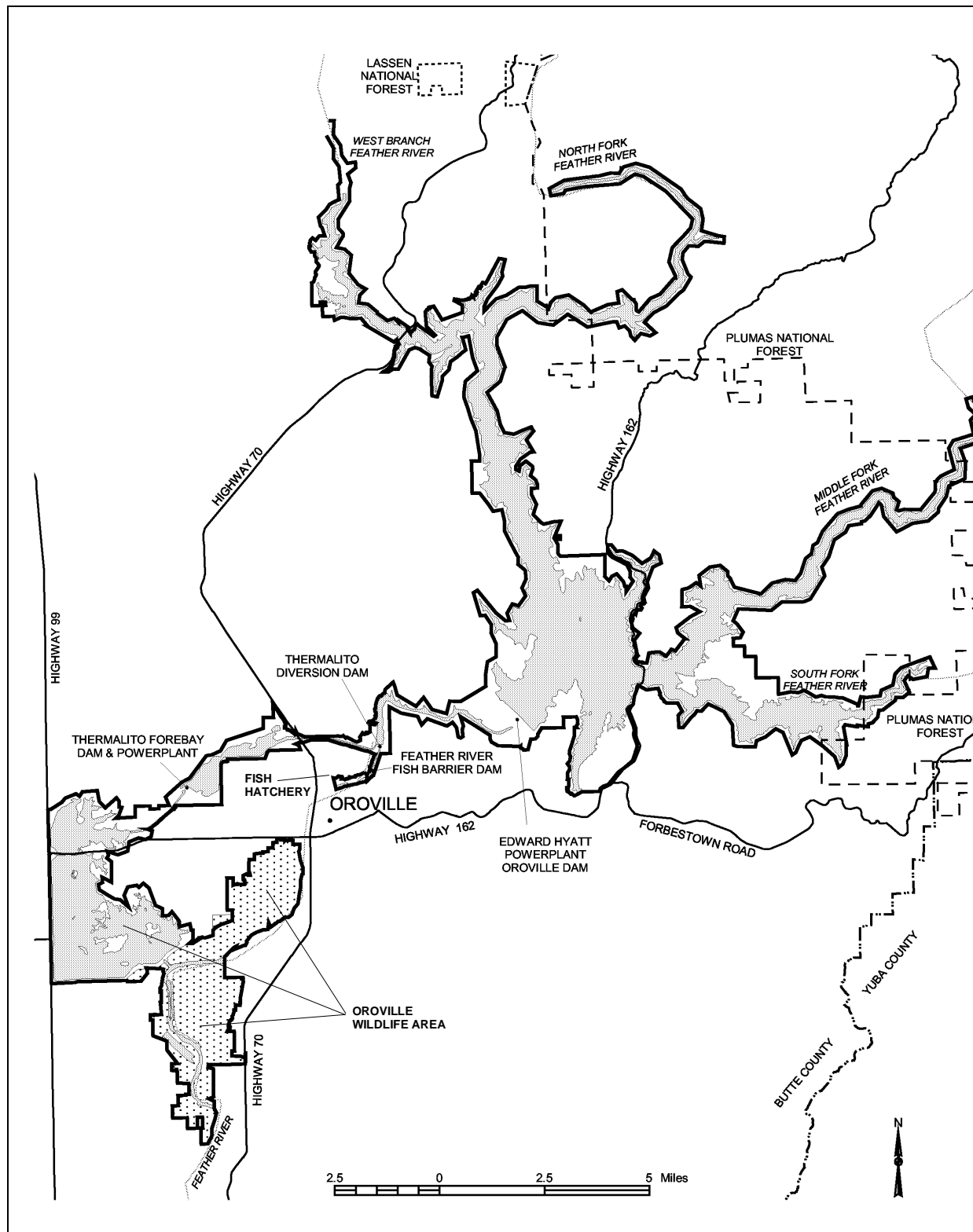


Figure 1.2-1. Oroville Facilities FERC Project Boundary

Preliminary Information – Subject to Revision – For Collaborative Process Purposes Only

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level (msl) in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG entitled, "Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife," sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the

Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The National Marine Fisheries Service has also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65°F on a daily average. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65°F from approximately April through mid May, and 59°F during the remainder of the growing season). There is no obligation for DWR to meet the rice

water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 (July 2002) af are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 maf. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 maf to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the

watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 NEED FOR STUDY

2.1 PURPOSE AND SCOPE

The operation of the Oroville Facilities may affect water temperature, which may influence rearing juvenile Steelhead trout (*Oncorhynchus mykiss*). Exposure of juvenile steelhead to high water temperatures may result in acute direct mortality or in sub-lethal chronic thermal stress that can be evidenced through indicators such as disease outbreaks and reduction in growth.

Laboratory studies on Feather River Hatchery and naturally spawned steelhead suggest that rearing juveniles prefer temperatures between 62 °F and 68 °F (16.7 °C and 20 °C) (Cech and Myrick 2000). Naturally spawned Feather River Steelhead have been observed to rear successfully at water temperatures near 65 °F (18.3 °C) (DWR and USBR 2000, Cavallo et al. 2003, DWR 2002a). Young-of-year Feather River steelhead have also been observed rearing in habitats where average daily water temperatures were greater than 63 °F (17.2 °C), and where daily maximal water temperature exceeded 66 °F (18.9 °C) (DWR and USBR 2000). To complement the existing laboratory study and the continued gathering of observational data by snorkeling (SP-F10, Task 3A), additional field studies were proposed. As part of Oroville Facilities Relicensing study plan F10, Task 3B, mark and recapture and enclosure growth experiments were conducted to evaluate the effects of temperature on juvenile steelhead growth and rearing behavior in the Low Flow Channel (LFC).

More specifically, the purpose of FERC study plan F10, Task 3B was to identify growth rates of steelhead rearing in different sections of the LFC of the lower Feather River. The intent was to identify any differences in growth rates between steelhead rearing in the upper (colder) and lower (warmer) areas of the LFC. By experimentally enclosing and rearing individual steelhead for up to three months, any obvious sub-lethal effects of rearing in a warmer environment would be reflected in the growth rates observed. Additionally, naturally spawned steelhead were marked and recaptured throughout the LFC in order to understand growth rates experienced in the wild. This report summarizes data collected from the enclosure and mark and recapture studies conducted in 2003.

3.0 STUDY OBJECTIVES

3.1 APPLICATION OF STUDY INFORMATION

River flow and water temperature have direct effects on habitat suitability for juvenile fishes. Operation of the Oroville Facility creates varying temperature regimes throughout the LFC. Subsequently, certain riffles may be more suitable for juvenile rearing than others. Flow and temperature recommendations for the LFC must consider the effects on juvenile steelhead. The information contained in this report can be used to evaluate the effects of operational changes in temperature on the growth of wild steelhead rearing in the LFC.

4.0 METHODOLOGY

4.1 ENCLOSURE EXPERIMENTS

4.1.1 Enclosure placement

Six identical enclosures were used to test the growth of juvenile steelhead forced to rear in two highly different temperature regimes. In order to subject the steelhead to such conditions, one upstream (colder) and one downstream (warmer) location within the LFC was selected. Hatchery (upstream) and Eye Riffle (downstream) were selected as the locations because of their historic use by wild steelhead. Each location had to provide enough space for the enclosures and adequately represent the rearing habitat available in the general area. Although it is impossible to place all six enclosures in areas that otherwise would be highly utilized by wild steelhead, every effort was made to ensure that the best available sites were chosen. Attempts to place enclosures at similar depths and velocities were unsuccessful, therefore velocity and depth profiles were different for each enclosure. Figures 4.1-2 and 4.1-3 illustrate the general positions of the enclosures within each riffle complex (See Appendix A for photographs of enclosures).

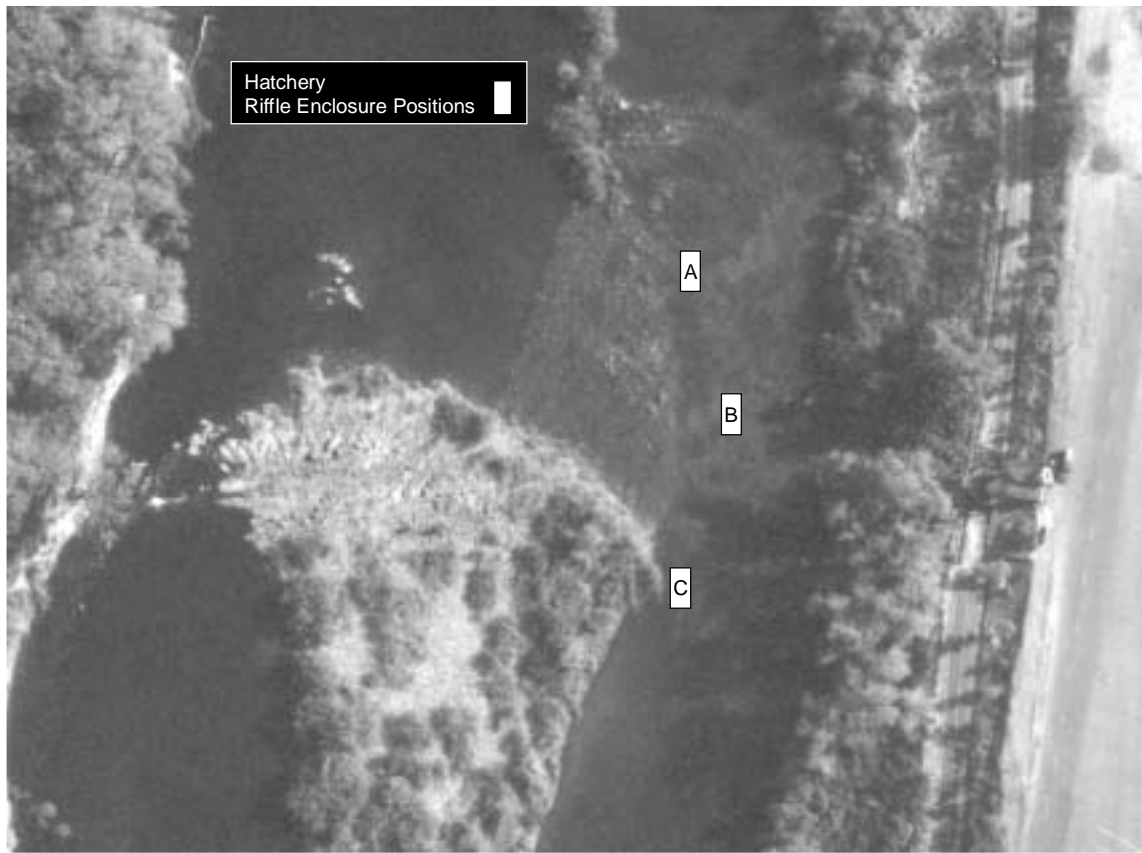


Figure 4.1-1. Hatchery Riffle enclosure positions, labeled A, B and C.



Figure 4.1-2. Eye Riffle side channel enclosures, labeled D, E and F.

4.1.2 Enclosure Design

Each enclosure consisted of a 4 ft x 8 ft aluminum structure designed to prevent 50 mm (2 in) steelhead from escaping while allowing food and water to enter. Steelhead placed in the enclosures were not fed, therefore the design of the front (and rear) screen had to provide adequate food resources for the most normal growth possible. The front and rear of each enclosure consisted of 3/16 inch vertical bars placed 1/8 inch apart. Field tests determined that this design would allow adequate water (and probably drifting prey) to enter the enclosure. The sides and bottom were constructed of a 3/16 inch square stainless steel weave, designed to allow water to flow through from all directions but still provide a sufficient fish barrier. Four cinder blocks (each 12 in x 6 in, with two large holes) were placed in each enclosure to provide similar current refuge and cover within each enclosure. One block was placed in each quarter of the enclosure to allow steelhead to find refuge in all areas of the enclosure.

4.1.3 Enclosure Sampling

In June, 2003, sixty Feather River Hatchery steelhead were individually marked with a colored elastomer (manufactured by Northwest Marine Technologies, Tumwater, WA), coded-wire-tagged and placed in one of six enclosures. All steelhead were visually inspected for obvious signs of disease. Only visually healthy, similar-sized steelhead were selected for the experiment. Thirty fish were placed in three enclosures at both Eye (10 fish per enclosure) and Hatchery Riffles (see Figures 4.1-1 and 4.1-2). At two-week intervals from June 2 through September 11, every steelhead was removed from the enclosure, measured to the nearest millimeter and weighed to the nearest 0.1 gram. If a fish was determined to be missing, a new similar sized Feather River Hatchery steelhead was marked and placed in the enclosure as soon as possible. Every attempt was made to ensure that ten fish were in each enclosure at all times. Upon completion of the experiment, all enclosure steelhead were sacrificed, dissected and visually inspected for obvious signs of disease (visual necropsy).

4.1.4 Invertebrate Drift Sampling

During bi-weekly site visits to the enclosures drift samples were collected in order to quantify relative macro-invertebrate drift at the two sites. Drift samples were collected by staking a 3.28 ft x 1.64 ft (1.0 m x 0.5 m) drift net (500 micron mesh) directly in front of each enclosure for approximately 20 minutes. Drift samples were always collected during the day at both enclosure locations (between 1000 and 1500 hours). Current velocity measurements were taken for each drift sample using a Price AA current meter.

Invertebrate drift collections were sub-sampled, sorted and identified to the lowest possible taxon. Invertebrates were quantified by determining the number of organisms per cubic meter of water sampled. Invertebrates were then ranked according to their abundance in the drift. Although zooplankton was present in most samples, plankton abundance was not quantified in the interest of time.

4.2 MARK AND RECAPTURE SAMPLING

The objective of mark and recapture sampling was to provide information complimentary to the enclosure of hatchery steelhead, but that would not have artifacts of the enclosure experiment. Repeated sampling of wild juvenile steelhead was designed to investigate site-fidelity and growth in cases where fish were marked and recaptured.

Steelhead sampled during mark and recapture experiments were collected by beach seining and backpack electrofishing (Smith Root Model 12 backpack electrofishing unit) at several riffles in the LFC. The riffles included Auditorium, Hatchery, Hatchery Ditch, Matthews, Aleck, Steep and Eye (See Figure 1.1-1). Fish were collected between

0900-1200 on a monthly or bi-weekly basis between June and August 2003. Upon collection, fish were placed in buckets of fresh river water. Unwanted species were released upon recovery. All steelhead and Chinook salmon were kept for further processing. Once each site was thoroughly sampled, all steelhead and Chinook were placed in chilled and aerated water for processing. All Chinook were measured and immediately released. All steelhead were anesthetized with TRICaine-S, (Brand of Tricaine Methanesulfonate, manufactured for Western Chemical, Inc.), weighed, measured (to the nearest fork length) and searched for unique tagging marks (after the initial tagging event). All unmarked steelhead greater than 50 mm were marked using latex elastomer. Every individual was assigned a unique mark using neon red, blue, orange, yellow, or green colored tagging material in various body locations. Tagging locations included nose, upper and lower caudal peduncle, and dorsal and anal fins. All fish were released as close to the original recapture site as possible. Steelhead mortalities were preserved for future research. Measurements of water temperature, effort, weather, and flow were also recorded during each sampling event.

Condition Factor (K) was used to assess changes in growth by location on a standardized basis. The following equation was used:

$$K = 100000 * W / FL^3$$

where W = weight in grams and FL = fork length in millimeters.

5.0. RESULTS

5.1. ENCLOSURE EXPERIMENTS

5.1.1 Steelhead Growth Experiments

Enclosure experiments conducted at Hatchery and Eye Riffles proved valuable for evaluating the potential success of steelhead rearing in two highly different temperature regimes in the LFC. Although growth was variable between and within sites, all fish maintained adequate growth throughout the experiment (Table 5.1.1-1 and Figure 5.1.1-1).

Table 5.1.1-1. Growth Rates of steelhead reared in enclosures.

Location	Enclosure	Velocity at Front of Enclosure (ft/s)	Depth at Front of Enclosure (m)	Mean growth/day (mm)	1 SD
Hatchery Riffle	A	0.85	0.28	0.70	0.15
	B	0.67	0.38	0.74	0.18
	C	0.69	0.52	0.82	0.26
Eye Riffle	D	1.67	0.40	0.54	0.14
	E	1.12	0.57	0.81	0.10
	F	0.72	0.58	0.62	0.23

Analysis of variance did not show a within site statistical difference for daily growth at Hatchery Riffle enclosures ($F=0.90$, $p=0.419$), but did for Eye Riffle ($F=6.89$, $p=0.004$). A t-test found no statistical difference between growth at Hatchery and Eye Riffles ($T=1.17$, $p=0.362$).

Condition factor (K) for the steelhead used in the enclosure experiments ranged from 1.05 to 1.17 and are reported on Table 5.3-2

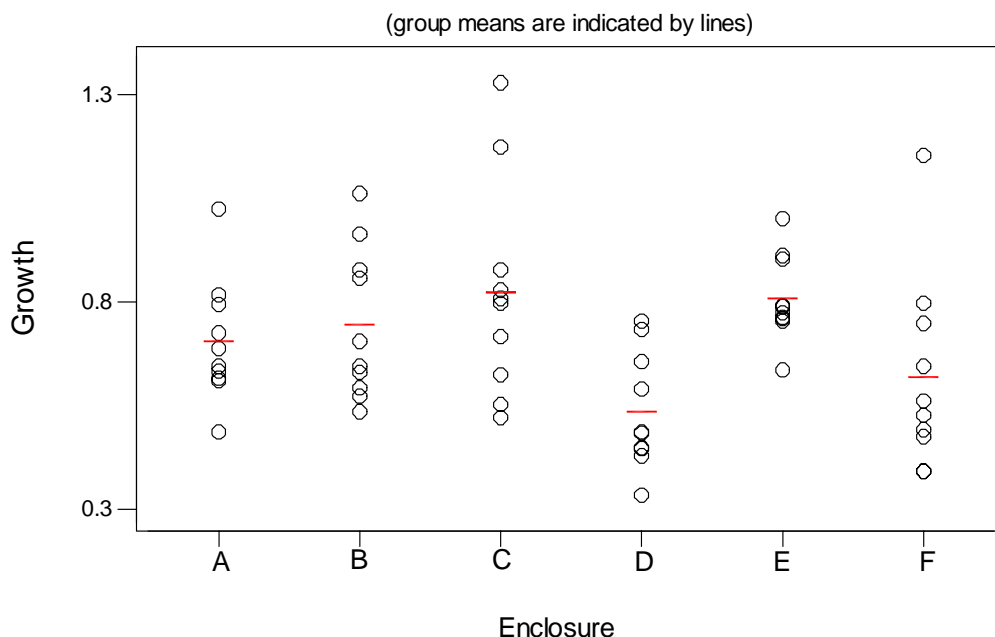


Figure 5.1.1-1. Dot plot of average growth per day (fork length in mm). Each circle represents an individual. Enclosures A, B, and C were located at Hatchery Riffle. Enclosures D, E, and F were located at Eye Riffle.

5.1.2 Invertebrate Sampling

Invertebrate drift samples collected throughout the study period indicate that overall abundance of macro-invertebrates is much greater at Hatchery Riffle than at Eye Side Channel (Figure 5.1.2-1). Dipterans (true flies) and Ephemeropterans (mayflies) were the most dominant invertebrates in the drift at both sample locations (Table 5.1.2-1). Catch per unit effort (CPUE) of all invertebrates was much greater for Hatchery Riffle than for Eye. The June sample period was the only time Eye Riffle invertebrate densities were similar to Hatchery Riffle. Except for the drop in catch at Eye Riffle between June 18 and July 1, invertebrate catch remained steady throughout the study period.

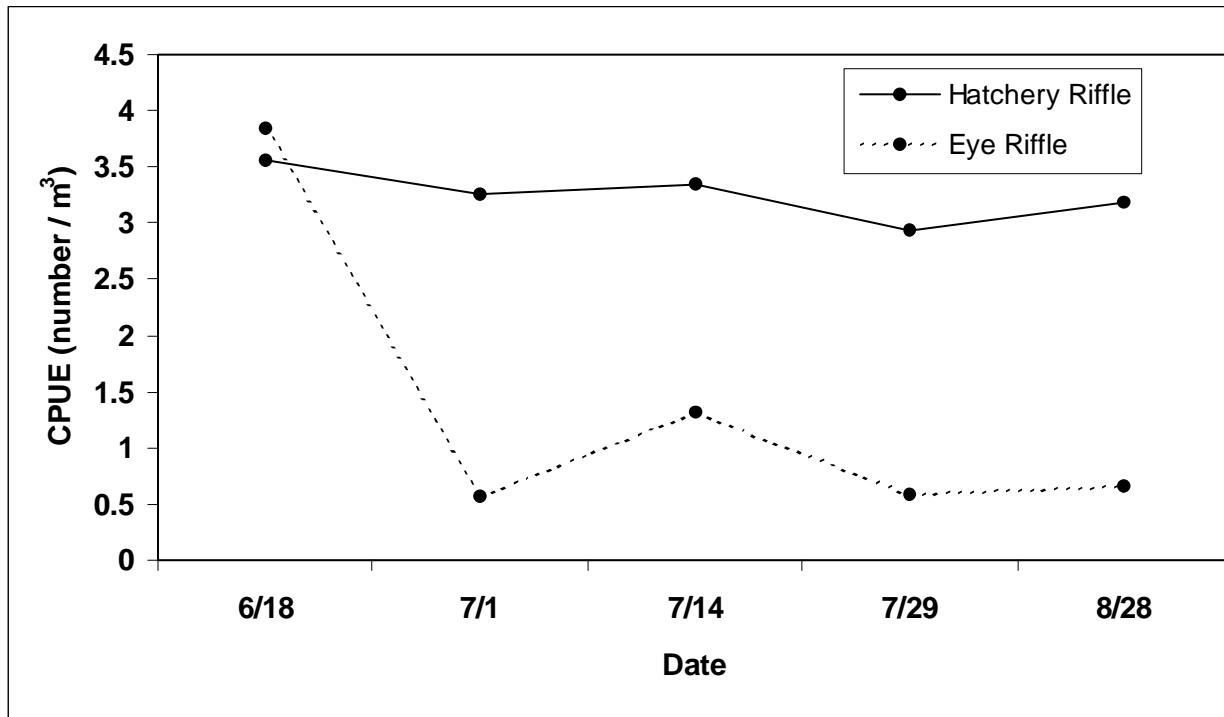


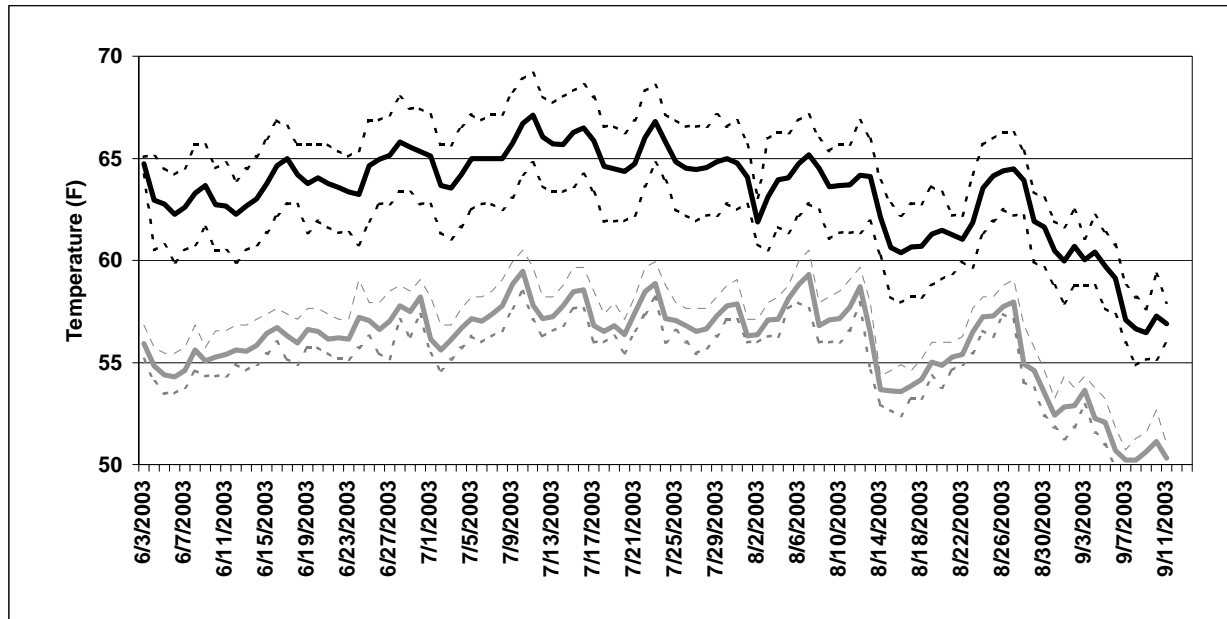
Figure 5.1.2-1. Catch per unit effort (CPUE) of all macro-invertebrates captured during drift sampling at Hatchery and Eye Riffle enclosures.

Table 5.1.2-1. Relative abundance (Percent) of 20 macro-invertebrates captured during drift sampling at Hatchery and Eye Riffles during the 2003 enclosure study.

Taxon	Common Name	Hatchery Riffle	Eye Riffle
Acari	Mites	3.7	6.5
Amphipoda	Amphipods	0.0	1.5
Annelida	Segmented worms	0.0	0.1
Arachnid	Spiders	0.2	0.0
Hydrozoa	Hydras	1.9	2.4
Coleoptera	Beetles	0.1	0.0
Conchostraca	Clam shrimps	0.2	6.6
Diptera	True Flies	61.9	19.5
Ephemeroptera	Mayflies	11.9	16.8
Gastropoda	Snails, Slugs	1.5	3.4
Hemiptera	True Bugs	1.2	5.0
Homoptera	Aphids, scales	8.8	7.2
Hymenoptera	Ants, Wasps, Bees	0.7	2.4
Lepidoptera	Butterflies, Moths	0.0	0.5
Nematoda	Roundworms	0.5	0.0
Oligochaeta	Segmented worms	2.8	8.9
Ostracoda	Mussel shrimp	0.6	9.7
Pelecypoda	Clams, mussels	0.5	3.8
Trichoptera	Caddisflies	2.6	5.3
Turbellaria	Flatworms	0.8	0.3

5.2 ENCLOSURE AND LOW FLOW CHANNEL WATER TEMPERATURES

Continuous logging temperature recorders (Onset Computer Corporation) were placed in enclosures at each location. Temperatures were recorded every 30 minutes throughout the study period (Figure 5.2-1). The average monthly temperature difference (degrees Fahrenheit) between Hatchery and Eye Riffles was 7.7 in June, 8.8 in July, and 7.5 in August.



Source: DWR, unpublished

Figure 5.2-1. Mean daily water temperature with minimum (--) and maximum (--) at Hatchery (—) and Eye Riffles (—) during the 2003 enclosure study.

Continuous logging temperature recorders were also placed at Bedrock, Matthews and Steep Riffles. Figure 5.2-2 better demonstrates the temperature regime of the entire LFC. As you move downstream in the LFC, water temperature rapidly increases. Generally, Lower Feather River water is warming as it progresses from the Fish Barrier Dam to the Thermalito Afterbay Outlet during June through mid-September.

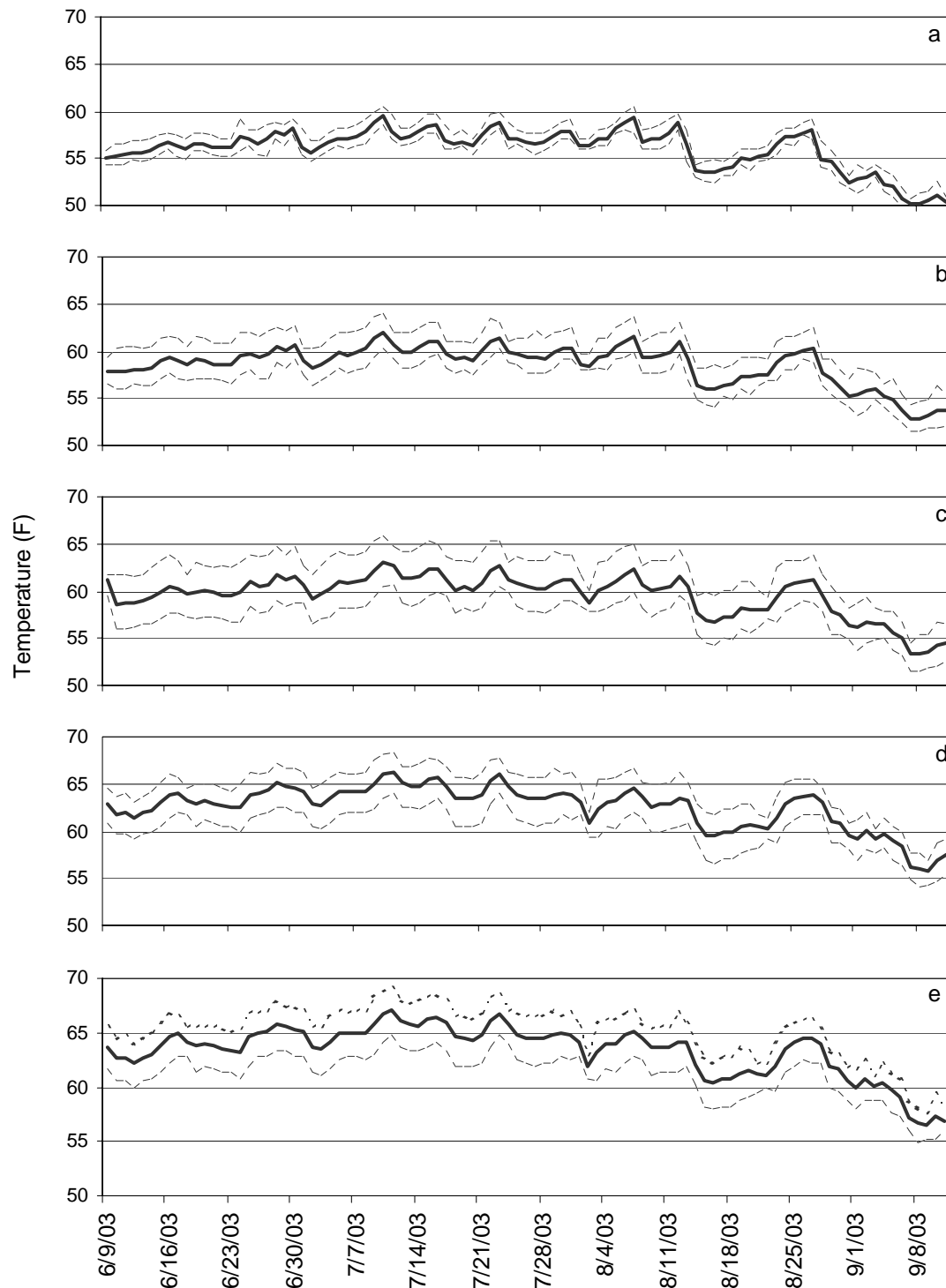


Figure 5.2-2. Mean daily temperature (—) with daily minimum (--) and maximum (---) for (a) Hatchery Riffle, (b) Bedrock Riffle, (c) Aleck Riffle, (d) Steep Riffle, and (e) Eye Riffle.

5.3 MARK AND RECAPTURE SAMPLING

In June, July and August we captured 985 wild steelhead, of which, 631 were large enough to be tagged. A total of 37 (3.8%) steelhead died during sampling. All mortalities were preserved for future otolith, stomach and genetic analysis. The majority of steelhead were captured at Hatchery Ditch (n=401), the fewest were captured at Bedrock Park (n=10). Catch per unit effort (CPUE) was greatest at Hatchery Ditch and lowest at Bedrock Park (Table 5.3-1). Bedrock Riffle and Eye Riffle were sampled as recapture locations only.

Of the 631 marked steelhead, 88 (13.9%) were recaptured. More steelhead were marked and recaptured in Hatchery Ditch than in any other location (51 recaptured out of 240 tagged, 21.3%). Of the 88 recaptures overall, 77 (87.5%) were recaptured in the same location they were initially marked. Five (5.7%) steelhead were recaptured downstream and six (6.8%) were recaptured upstream of their original release location. Mean fork length of all fish sampled (marked or unmarked) was largest at Eye Riffle, smallest at Auditorium/Hatchery Riffle.

Table 5.3-1. Summary of sampling effort, recapture rate and fork length data of steelhead collected during mark and recapture sampling.

Location (River Mile)	Total Number of Steelhead Captured	Number of Steelhead Tagged	Percent of all Steelhead tagged	Number and (%) of steelhead recaptured	CPUE: steelhead/ minute (\pm 1 SD)	Mean Fork Length (mm) (\pm 1 SD)
Hatchery Ditch (66.6)	401	240	38.0	51 (21.3)	3.4 (1.3)	69.7 (16.9)
Auditorium/ Hatchery Riffle (66.7)	120	78	12.4	0 (0)	0.9 (0.7)	62.2 (18.9)
Bedrock Riffle (65.8)	10	0	n/t	0 (0)	0.8 (--)	86.0 (24.5)
Matthews Riffle (64.1)	86	23	3.6	2 (8.7)	1.7 (0.4)	94.5 (33.3)
Aleck Riffle (63.5)	171	142	22.5	16 (11.3)	2.6 (1.5)	89.1 (21.0)
Steep Riffle (61.0)	183	148	23.5	19 (12.8)	1.2 (0.8)	100.0 (37.2)
Eye Riffle (60.1)	14	0	n/t	0 (0)	1.7 (1.9)	124.6 (22.9)

n/t = no steelhead tagged at this location

Steelhead marked and recaptured in Hatchery Ditch grew significantly slower than steelhead marked in Aleck and Steep Riffles (Figure 5.3-1). The relatively small sample size prevented the inclusion of data from Matthews and Auditorium Riffle in this analysis.

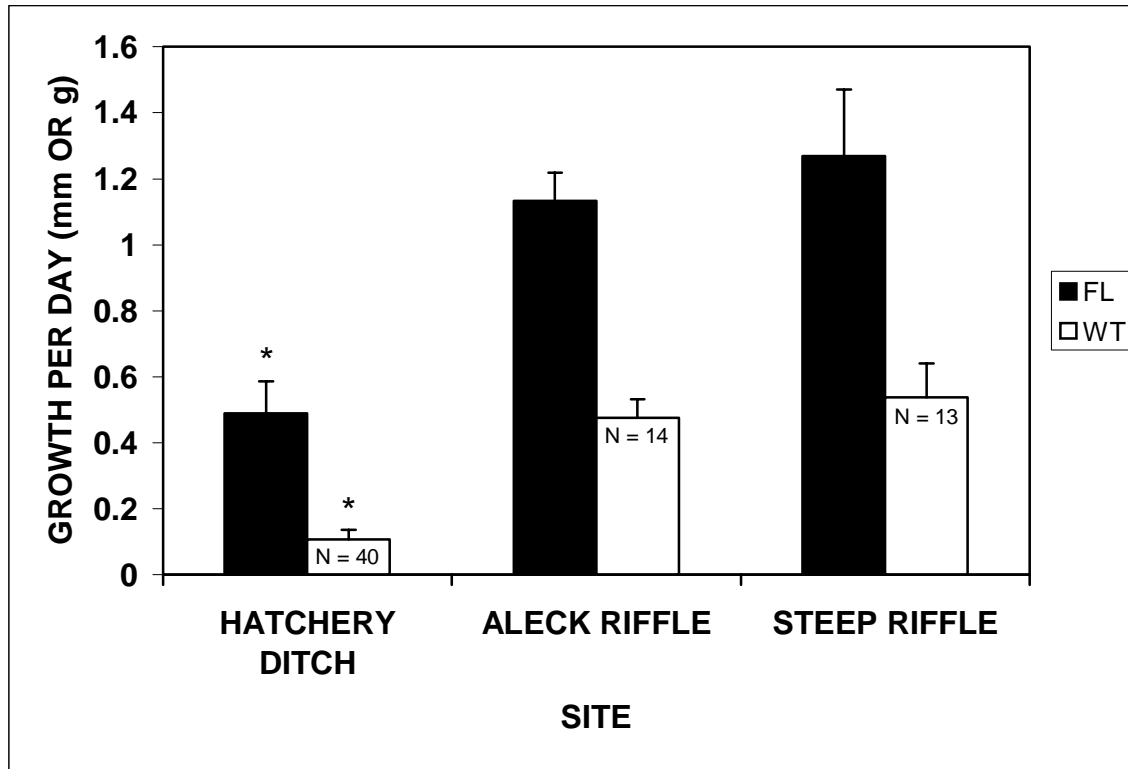


Figure 5.3-1. Growth of wild steelhead in millimeters (Fork Length-FL) and grams (Weight-WT) at three Low Flow Channel locations. Data are from steelhead marked and recaptured at the same location. Asterisk (*) indicates a significant difference (for FL, $F= 11.69$, $p<.0001$; for WT, $F=24.49$, $p<.0001$). Anova table is included in Appendix B.

Of all marked steelhead, condition factor (K) was highest at Steep and Matthews Riffles (K=1.40), lowest in Hatchery Ditch Riffle (1.20) (Table 5.3-2). All riffle locations averaged a condition factor well above 1.0, indicating that most Feather River steelhead were in good physical health when sampled (based on physical appearance and condition factor).

Table 5.3-2. Summary of Condition Factors (K) determined from the enclosure and mark and recapture studies. Bedrock and Eye Riffles were not included due to small sample size.

Location	River Mile	Mean K (1 SD)	Sample size (n)
Enclosures			
Hatchery Initial (all enclosures)	66.6	1.05 (0.16)	30
Hatchery Final (all enclosures)	66.6	1.09 (0.07)	30
Eye Initial (all enclosures)	60.1	1.05 (0.13)	30
Eye Final (all enclosures)	60.1	1.17 (0.09)	30
Riffles			
Hatchery Ditch	66.6	1.20 (0.16)	240
Auditorium	66.7	1.22 (0.13)	77
Matthews	64.1	1.40 (0.11)	23
Aleck	63.5	1.30 (0.12)	142
Steep	61.0	1.40 (0.13)	148

Source: DWR, unpublished

6.0 DISCUSSION AND CONCLUSIONS

All fish held for greater than 30 days during the enclosure study showed an increase in growth and condition factor (K). Growth data obtained from enclosure studies provides valuable insight into the growth of juvenile steelhead rearing in two highly different temperature regimes. Although artificial, an average growth rate of 0.76 (Hatchery Riffle) and 0.65 mm per day (Eye Riffle Side Channel) of steelhead living in enclosures indicates a suitable rearing environment. Furthermore, average condition factor (K) increased throughout the study period, indicating that overall physical condition was improving. When compared to wild fish, steelhead reared in enclosures had only slightly lower condition factor values, an indication they were receiving appropriate amounts of food with respect to their metabolic needs (based primarily on fish size, temperature and current velocities). Additionally, except for one fish that was known to have died during the study (Eye Riffle), no steelhead showed visual signs of stress from either competition or temperature (i.e. skin lesions, fin rot, bite marks, emaciation, lethargy). On the contrary, during site visits and subsequent dissection (visual necropsy), all steelhead appeared healthy, satiated, energetic, and all displayed normal color.

Complications derived from vandalism and enclosure design prevented holding many of the original subjects throughout the entire study period. This resulted in a nominal loss of data that would have better represented actual growth for each location. For example, between weeks four and six of the experiment, all of the steelhead in enclosure F (Eye Riffle) escaped after significant vandalism. At the time of their escape, these fish were growing at a rate of 0.84 mm per day. Growth of steelhead placed in the same enclosure after the vandalism occurred was only 0.62 mm per day. The data from the replacement steelhead was used in the subsequent analysis because the replacement steelhead were in the enclosures for a longer period of time. Using the data from the replacement steelhead lowered the overall growth rate for enclosure F, thereby reducing the overall growth rate experienced at Eye Riffle. It is unlikely, however, that the 0.84 mm growth rate would have continued at the same rate throughout the experiment. It is more likely that as the smaller (approximately 60 mm) steelhead became acclimated to their new surroundings, they began feeding aggressively and growing rapidly. As they became larger (perhaps 100 mm), growth likely slowed due to competition for food and space within the enclosure. Growth was over twice as fast at Hatchery Riffle and one and a half times as fast at Eye Riffle during the first month of the study as compared to the last. Unfortunately, because these fish were lost from the experiment (as previously mentioned-enclosure F), their data could not be used in subsequent comparative analyses, thereby weakening the growth comparison between the two locations. Even without this data and other less severe losses (fish escaping from vandalism) experienced during the study, there was still adequate data to determine that growth in the enclosures was not appreciably different between the two locations.

Although observed growth was similar between the two locations, invertebrate drift was not. Even though Hatchery Riffle drift samples had considerably more invertebrates and Eye Riffle steelhead were subject to a much warmer temperature regime, enclosure growth was still very similar between the sites. Based on mark and recapture studies of wild steelhead, it was expected that Eye Riffle steelhead would grow significantly faster than those rearing at Hatchery Riffle. Differences between Hatchery and Eye Riffle were not observed because the enclosures probably function as an equalizer between sites with different food resources and temperature regimes. Despite every attempt to design a structure that would allow water and drifting prey to freely enter, some debris loading occurred, thereby preventing normally available food sources from entering. Although the amount of drifting prey (outside the enclosure) was much greater at Hatchery Riffle, steelhead living in the enclosures were probably similarly limited in growth due to food limitations created by the bars on the front and rear of the enclosures. Furthermore, as certain steelhead grew faster than others within the enclosure, they were probably more likely to set up the best feeding locations. With limited space, growth of the smaller steelhead was likely to suffer. As the larger steelhead grew rapidly and became more aggressive, smaller steelhead, although maintaining adequate growth, could not be expected to grow at the rate of their wild counterparts. Although condition factors were similar between wild and enclosed steelhead, wild steelhead rearing in the lower sections of the LFC grew much faster than those rearing in the enclosures. Interestingly, steelhead rearing in enclosures at Hatchery Riffle actually grew faster than wild steelhead rearing in Hatchery Ditch. Even though the temperature regimes of Hatchery Ditch and Hatchery Riffle are very similar, it is possible that the high density of steelhead rearing in Hatchery Ditch limits growth rates (Cavallo et al. 2003). The temperature regime steelhead were exposed to was undoubtedly another factor influencing observed growth in the enclosures.

Water temperature affects every life stage of salmonids. Thermal tolerances are a function of exposure times and acclimation temperatures (Brett 1952). Fish acclimated at higher water temperatures tend to exhibit increased tolerance of higher water temperatures than fish acclimated to cooler water temperatures. Water temperature can influence many aspects of the life history of juvenile salmonids including growth rates, susceptibility to disease, and smoltification. All of these factors ultimately influence survivability. Cech and Myrick determined that Feather River steelhead preferred temperatures in the range of 62 to 68 degrees Fahrenheit (16.7 to 20 degrees Celsius)(Cech and Myrick 2000). This coincides very well with temperatures observed at Eye and Steep riffles during the summer of 2003 (Figure 5.2-2). The range of temperatures observed throughout the LFC during the summer of 2003 was substantial. Eye Riffle was on average eight degrees (Fahrenheit) warmer than Hatchery Riffle. It is clear that metabolic demands placed on fish rearing in such highly different temperature regimes will be different. Steelhead rearing in a warmer environment (such as Eye Riffle) will have increased metabolic demands. Food resources must be sufficient to allow for suitable growth. Although drift samples collected at Hatchery Ditch contained three to four times the number of macro-invertebrates, observed growth between Eye

and Hatchery Riffle enclosure steelhead was minimal. Furthermore, wild steelhead that were marked and recaptured showed greatest growth at Steep Riffle (just upstream of Eye Riffle), more than twice the rate of fish marked and recaptured in Hatchery Ditch (near Hatchery Riffle) (Figure 5.3-1). Additionally, the average fork length of steelhead captured at Auditorium/Hatchery Riffles and Hatchery Ditch was anywhere from 30 to 60 millimeters less than fish captured at Steep and Eye Riffles. It is clear that steelhead captured in upper sections of the LFC (Hatchery Ditch, Auditorium, Hatchery Riffles) are consistently smaller than those captured in lower sections (Steep and Eye Riffles). Under the observed temperature regime, metabolic demands of steelhead rearing in lower sections of the LFC are apparently being met.

Although apparently suitable, temperatures exceeding those observed during this study would likely have detrimental affects. Thermal stress loading occurs when water temperatures are outside suitable ranges which, can cause immediate or delayed mortalities (Brett 1952). However, growth is a function of temperature. If water temperatures are not optimal for growth, a decrease in the survivability of juvenile salmonids may occur (Folmar et al. 1982). If temperatures are within optimal ranges, growth will likely be constrained by food availability and competition for such resources. Warmer temperatures (within species specific tolerance ranges) are most likely to provide the most favorable growing conditions. Cech and Myrick (2000) demonstrated that Feather River steelhead preferred water between 62 and 68 degrees Fahrenheit. Nimbus Hatchery steelhead showed increasing growth to 66.2 degrees Fahrenheit (Cech and Myrick 1999). According to this criteria, steelhead rearing at Eye Riffle were generally subjected to suitable temperatures, with Hatchery Riffle temperatures often less suitable for rapid growth. Wild steelhead marked at Steep Riffle (just upstream from Eye Riffle) grew over twice as fast as steelhead marked in Hatchery Ditch (near Hatchery Riffle). If growth rate is an important factor in determining what temperatures are suitable, then it would appear that the temperature regime observed near Steep Riffle (in summer 2003) is optimal for steelhead growth in the Feather River. Clearly, fish are not only succeeding in the lower sections of the LFC, they are thriving, growing more than twice as fast as steelhead rearing in the upper sections of the LFC.

Although the focus of this study was on the relationship between growth and rearing location (temperature), it is important to remember that water temperatures not only influence growth, but also the virulence of disease-causing organisms. Salmonids are susceptible to a variety of diseases, each of which typically has water temperature ranges at which virulence is highest. While certain diseases are more prevalent in cold water, most of the more significant diseases afflicting salmonids increase in virulence and severity as water temperatures increase (Boles et al. 1988; Materna 2001). The parasite *Ceratomyxa shasta* is present in the Feather River and could infect steelhead. The parasite is not spread by contact, but rather by exposing fish to the infective form of the parasite residing within the substrate. External signs of the disease include lethargy and distended abdomen. Internal signs include tumors, intestinal inflammation and muscular lesions. Progress of *C. shasta* accelerates as temperature

increases (Bartholomew et al. 1989). Depending upon the specific temperature of their rearing environment, steelhead rearing in the Low Flow Channel would be expected to show obvious signs of distress within a few weeks or months after infection. No steelhead processed during mark and recapture or enclosure sampling showed any visible signs of disease or stress.

Mark and recapture studies of wild steelhead performed in 2003 suggest that steelhead rearing in lower sections of the LFC actually outperform those rearing in upper sections. Growth was over twice as fast at Steep Riffle as compared to Hatchery Ditch. Although clearly faster in lower sections, mark and recapture studies demonstrate that growth is probably sufficient throughout the LFC. Furthermore, the recapture rates observed among marked steelhead confirms that many juvenile steelhead found throughout the LFC are not actively emigrating, but are more likely rearing throughout the summer months. If temperatures at Steep Riffle were unsuitable, there is no reason to expect that steelhead would continue to rear there for any length of time. Additionally, mark and recapture data suggest that steelhead rear and thrive in lower LFC locations throughout the summer. Although physical differences exist between the upper and lower sections of the LFC, water temperature remains the most significant. It is probable that the growth differences observed in this study were directly related to the highly different temperature regimes steelhead were experiencing throughout the study. Mark and recapture studies reveal that water temperatures observed near Steep and Eye Riffles (assuming adequate food and habitat resources) probably provide optimal growing conditions for over-summering juvenile steelhead.

The temperature regime experienced at Steep and Eye Riffles in summer 2003 was expected to produce rapid growth for juvenile steelhead. However, the optimal temperature regime alone will not provide sufficient steelhead rearing habitat. The importance of cover (riparian and in-stream), its association with appropriate feeding stations and temperature all play a critical role in producing rapid growth. For example, even though the productive riffle area (for invertebrates) of Hatchery Riffle is roughly 10 times the size of Eye Side Channel and twice as large as Steep Riffle, average fork length of wild steelhead captured at Eye and Steep Riffles was on average 62 and 38 millimeters larger than Hatchery Riffle, respectively. Even with the apparent discrepancies in invertebrate production, growth rates of marked and recaptured wild steelhead were far greater at Steep Riffle. Furthermore, growth of enclosure steelhead was similar between Hatchery Riffle and Eye Side Channel. Although providing what is probably optimal growing temperatures for steelhead, the temperature regime observed at Eye Riffle is approaching the upper limits of steelhead tolerance ranges. Any increase in temperature at Eye Riffle would likely inhibit steelhead growth. Flow regimes proposed for the LFC must consider basic physical habitat requirements and the effects that water temperature could have on the resulting growth rates of juvenile steelhead. The combination of small side channels (complex microhabitats), increased cover and appropriate water temperatures create the most productive rearing habitat for juvenile steelhead in the lower Feather River.

7.0 REFERENCES

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Appendix A

Photographs of Eye and Hatchery Riffle Enclosures.



Eye Riffle Side Channel Enclosure, Looking Downstream



Eye Riffle Side Channel, Enclosure Close-up



Hatchery Riffle enclosures looking downstream

Appendix B

Anova table of Mark and Recaptured Steelhead from Hatchery Ditch, Aleck Riffle and Steep Riffle.

Anova table of Mark and Recaptured Steelhead from Hatchery Ditch,
Aleck Riffle and Steep Riffle.

Growth FL

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>SD</i>
Hatchery Ditch	40	19.5448	0.48862	0.384121	0.619775
Aleck	14	15.8707	1.133621	0.102007	0.319385
Steep	13	16.4978	1.269062	0.523323	0.723411

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	8.254329	2	4.127165	11.69444	4.69E-05	3.140443
Within Groups	22.58667	64	0.352917			
Total	30.841	66				

Growth WT

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>sd</i>
Hatchery Ditch	40	4.307113	0.107678	0.030594	0.174912
Aleck	14	6.657407	0.475529	0.044824	0.211716
Steep	13	7.001104	0.538546	0.133222	0.364995

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	2.582623	2	1.291312	24.49039	1.26E-08	3.140443
Within Groups	3.374546	64	0.052727			
Total	5.957169	66				

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Appendix C

Individual growth data for enclosure steelhead.

Growth investigations of wild and hatchery steelhead in the lower Feather River
Oroville Facilities P-2100 Relicensing

Hatchery Riffle-Enclosure A										Overall Growth	Growth per day
		6/5/2003	6/16/2003	7/1/2003	7/15/2003	7/30/2003	8/12/2003	8/25/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12	Week 14		
Fish ID	1	O nose	O nose								
Fork Length (mm)		62	66	85	100	114	122	130	137	71	0.82
Weight (g)		2.21	3.25	6.6	11.4	15.6	21.1	25	26.54	23.29	0.27
Date placed in enclosure		6/5/2003	6/17/2003								
Fish ID	2	G nose	G nose								
Fork Length (mm)		68	55	79	94	110	112	119	124	69	0.79
Weight (g)		2.82	2.75	6	10.7	15.8	18.5	20.3	20.7	17.95	0.21
Date placed in enclosure		6/5/2003	6/17/2003								
Fish ID	3	O LP	R nose								
Fork Length (mm)		62	64	78	91	102	106	111	117	53	0.61
Weight (g)		1.99	2.69	5.3	9	12.7	12.8	14.8	16.06	13.37	0.15
Date placed in enclosure		6/5/2003	6/17/2003								
Fish ID	4	G LP	G LP	P nose							
Fork Length (mm)		64	63	88	97	110	117	127	136	48	0.69
Weight (g)		2.45	2.57	8.7	10.8	16.1	18.5	23.3	28.04	19.34	0.28
Date placed in enclosure		6/5/2003	6/17/2003	7/3/2003							
Fish ID	5	O UP	R nose cl.	R nose cl.							
Fork Length (mm)		62	61	78	87	106	n/d	108	112	34	0.49
Weight (g)		2.39	2.88	5.1	7.4	10.5	n/d	12.3	14.99	9.89	0.14

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Oroville Facilities Relicensing Team

March 23, 2004

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Growth investigations of wild and hatchery steelhead in the lower Feather River
Oroville Facilities P-2100 Relicensing

Hatchery Riffle-Enclosure A										Overall Growth	Growth per day
		6/5/2003	6/16/2003	7/1/2003	7/15/2003	7/30/2003	8/12/2003	8/25/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12	Week 14		
Date placed in enclosure		6/5/2003	6/17/2003	7/3/2003							
Fish ID	6	O nose cl.	O nose cl.								
Fork Length (mm)		65	66	77	89	99	104	112	121	55	0.63
Weight (g)		2.71	2.42	5	8.1	11.5	12.9	15.9	17.92	15.5	0.18
Date placed in enclosure		6/5/2003	6/17/2003								
Fish ID	7	G nose cl.	G nose cl.								
Fork Length (mm)		64	67	78	92	106	112	121	130	63	0.72
Weight (g)		2.48	3.62	6.2	9.7	15.1	16.6	20.7	23.37	19.75	0.23
Date placed in enclosure		6/5/2003	6/17/2003								
Fish ID	8	O LP cl.	R LP	P nose cl.							
Fork Length (mm)		60	61	82	90	103	110	116	125	43	0.61
Weight (g)		2.08	2.7	6.3	8	12.6	15.3	18.3	21.37	15.07	0.22
Date placed in enclosure		6/5/2003	6/17/2003	7/3/2003							
Fish ID	9	G LP cl.	G LP cl.								
Fork Length (mm)		60	62	75	90	101	106	113	118	56	0.64
Weight (g)		2.03	2.34	5.1	8.7	11.8	13.4	16.1	16.88	14.54	0.17
Date placed in enclosure		6/5/2003									
Fish ID	10	O UP cl.	R LP cl.								

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Growth investigations of wild and hatchery steelhead in the lower Feather River
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Hatchery Riffle-Enclosure A										Overall Growth	Growth per day
		6/5/2003	6/16/2003	7/1/2003	7/15/2003	7/30/2003	8/12/2003	8/25/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12	Week 14		
Fork Length (mm)		63	69	87	106	126	138	148	158	89	1.02
Weight (g)		2.11	3.78	8.2	14.9	24.6	32.4	37.4	43.03	39.25	0.45
Date placed in enclosure		6/5/2003	6/17/2003								

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Hatchery Riffle- Enclosure B											Overall Growth	Growth per day
		6/5/2003	6/16/2003	7/1/2003	7/15/2003		7/30/2003	8/12/2003	8/25/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6		Week 8	Week 10	Week 12	Week 14		
Fish ID	1	O nose										
Fork Length (mm)		62	69	85	97		106	113	120	120	58	0.59
Weight (g)		2.31	4.18	8	10.9		14.6	16.3	20	19.06	16.75	0.17
Date placed in enclosure		6/5/2003										
Fish ID	2	G nose		P nose								
Fork Length (mm)		60	66	75	84		91	98	107	115	40	0.57
Weight (g)		2.04	3.41	4.9	7.6		8.3	10.6	13.5	17.13	12.23	0.17
Date placed in enclosure		6/5/2003		7/3/2003								
Fish ID	3	O LP		P nose cl.								
Fork Length (mm)		61	69	78	88		96	106	114	123	45	0.64
Weight (g)		2.13	4.03	5.8	8		10.5	13.5	18.4	21.02	15.22	0.22
Date placed in enclosure		6/5/2003		7/3/2003								
Fish ID	4	G LP										
Fork Length (mm)		65	74	96	110		123	133	142	149	84	0.86
Weight (g)		2.66	4.93	11.8	18.2		22.7	28.7	32.4	37.82	35.16	0.36
Date placed in enclosure		6/5/2003										
Fish ID	5	O UP										
Fork Length (mm)		63	71	94	109		122	131	142	n/d	79	0.96
Weight (g)		2.39	4.28	11	16		21.7	26.3	35.2	n/d	32.81	0.40

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Hatchery Riffle- Enclosure B											Overall Growth	Growth per day
		6/5/2003	6/16/2003	7/1/2003	7/15/2003		7/30/2003	8/12/2003	8/25/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6		Week 8	Week 10	Week 12	Week 14		
Date placed in enclosure		6/5/2003										
Fish ID	6	O nose cl.										
Fork Length (mm)		63	71	90	104		117	124	128	132	69	0.70
Weight (g)		2.37	4.34	10	13.8		18.8	21.5	24	27.68	25.31	0.26
Date placed in enclosure		6/5/2003										
Fish ID	7	G nose cl.										
Fork Length (mm)		61	71	88	102		114	123	134	147	86	0.88
Weight (g)		2.16	4.07	8.1	10.9		15.5	19.1	25	31.89	29.73	0.30
Date placed in enclosure		6/5/2003										
Fish ID	8	O LP cl.	R nose cl.									
Fork Length (mm)		63	61	74	88		95	100	109	115	54	0.63
Weight (g)		2.39	2.88	5.1	7.9		10.5	11.6	14.9	16.7	13.82	0.16
Date placed in enclosure		6/5/2003	6/17/2003									
Fish ID	9	G LP cl.										
Fork Length (mm)		65	76	101	116		135	149	158	169	104	1.06
Weight (g)		2.58	5.3	13.6	19.2		30.4	39.7	45.8	53.09	50.51	0.52
Date placed in enclosure		6/5/2003										
Fish ID	10	G UP cl.	R nose			R nose, R LP cl.						

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Hatchery Riffle- Enclosure B											Overall Growth	Growth per day
		6/5/2003	6/16/2003	7/1/2003	7/15/2003		7/30/2003	8/12/2003	8/25/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6		Week 8	Week 10	Week 12	Week 14		
Fork Length (mm)		60	60	73	87	95	100	107	115	125	30	0.54
Weight (g)		2.29	2.17	5.2	8.6	11.2	10.5	13.7	17.8	22.01	10.81	0.19
Date placed in enclosure		6/5/2003	6/17/2003			7/17/2003						

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Hatchery Riffle-Enclosure C										Overall Growth	Growth per day
		6/5/2003	6/16/2003	7/1/2003	7/15/2003	7/30/2003	8/12/2003	8/25/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12	Week 14		
Fish ID	1	O nose									
Fork Length (mm)		61	70	90	112	n/d	115	118	122	61	0.62
Weight (g)		2.29	4.18	11.6	13	n/d	17.1	18.3	19.67	17.38	0.18
Date placed in enclosure		6/5/2003									
Fish ID	2	G nose									
Fork Length (mm)		62	69	90	107	112	134	140	148	86	0.88
Weight (g)		2.4	4.01	10	16.1	16.8	29.7	32.7	37.47	35.07	0.36
Date placed in enclosure		6/5/2003									
Fish ID	3	O LP									
Fork Length (mm)		65	75	100	116	126	131	138	143	78	0.80
Weight (g)		2.63	5.28	13.9	19.4	26.7	26.6	31.2	33.42	30.79	0.31
Date placed in enclosure		6/5/2003									
Fish ID	4	G LP									
Fork Length (mm)		60	66	81	92	101	104	108	111	51	0.52
Weight (g)		2.04	3.67	7	9.9	12.5	13.3	15	15.38	13.34	0.14
Date placed in enclosure		6/5/2003									
Fish ID	5	G UP									
Fork Length (mm)		66	74	94	101	115	118	120	120	54	0.55
Weight (g)		2.76	5.19	12.1	16.2	19.1	16.6	19.2	17.22	14.46	0.15
Date placed in enclosure		6/5/2003									

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Hatchery Riffle-Enclosure C										Overall Growth	Growth per day
		6/5/2003	6/16/2003	7/1/2003	7/15/2003	7/30/2003	8/12/2003	8/25/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12	Week 14		
Fish ID	6	O nose cl.									
Fork Length (mm)		65	73	97	114	128	133	140	146	81	0.83
Weight (g)		2.79	5.11	14	21.3	28.7	31.2	33.7	35.9	33.11	0.34
Date placed in enclosure		6/5/2003									
Fish ID	7	G nose cl.									
Fork Length (mm)		63	75	98	116	127	130	133	133	70	0.71
Weight (g)		2.6	5.1	13.1	20.7	24.8	26.1	27.2	26.84	24.24	0.25
Date placed in enclosure		6/5/2003									
Fish ID	8	O LP cl.									
Fork Length (mm)		69	79	107	128	143	155	168	184	115	1.17
Weight (g)		3.03	6.22	17	30.3	39.8	48	58.6	73.7	70.67	0.72
Date placed in enclosure		6/5/2003									
Fish ID	9	G LP cl.									
Fork Length (mm)		67	77	101	119	133	138	142	146	79	0.81
Weight (g)		2.73	5.28	13.3	18.5	26.1	27.2	28.9	29.98	27.25	0.28
Date placed in enclosure		6/5/2003									
Fish ID	10	G UP cl.									
Fork Length (mm)		65	76	99	113	138	n/d	n/d	n/d	73	1.33
Weight (g)		2.76	5.28	13.8	21.1	26.6	n/d	n/d	n/d	23.84	0.43
Date placed in enclosure		6/5/2003									

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Eye Riffle-Enclosure D											Overall Growth	Growth per day
		6/2/2003	6/16/2003	7/1/2003	7/14/2003		7/29/2003	8/11/2003	8/26/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6		Week 8	Week 10	Week 12	Week 14		
Fish ID	1	P LP	O nose cl.									
Fork Length (mm)		60	64	72	81		93	103	104	121	57	0.66
Weight (g)		2.1	2.41	4.4	6.7		9.8	13	18.1	20.24	17.83	0.20
Date placed in enclosure		6/2/2003	6/17/2003									
Fish ID	2	Pk LP	O nose	R nose cl.	R nose cl.	R LP cl.						
Fork Length (mm)		63	60	79	81	96	98	109	121	129	33	0.59
Weight (g)		2.61	1.96	6	6.1	9.3	10.1	13.3	18.9	21.97	12.67	0.23
Date placed in enclosure		6/2/2003	6/17/2003	7/3/2003	7/14/2003	7/17/2003						
Fish ID	3	W LP	Y nose	R nose								
Fork Length (mm)		64	82	78	80		90	101	106	112	34	0.49
Weight (g)		2.33	6.99	5.8	6.2		8.6	11.8	14.1	15.39	9.59	0.14
Date placed in enclosure		6/2/2003	6/17/2003	7/3/2003								
Fish ID	4	O LP	O LP									
Fork Length (mm)		62	61	68	75		85	92	97	100	39	0.45
Weight (g)		2.32	2.27	3.8	4.8		6.9	9.1	10	10.32	8.05	0.09
Date placed in enclosure		6/2/2003	6/17/2003									
Fish ID	5	G LP		P nose cl.								
Fork Length (mm)		68	90	74	76		82	95	100	104	30	0.43
Weight (g)		2.84	9.28	5.3	5.2		7.3	10.5	13.2	14.54	9.24	0.13
Date placed in enclosure		6/2/2003		7/3/2003								

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Eye Riffle-Enclosure D											Overall Growth	Growth per day
		6/2/2003	6/16/2003	7/1/2003	7/14/2003		7/29/2003	8/11/2003	8/26/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6		Week 8	Week 10	Week 12	Week 14		
Fish ID	6	P UP										
Fork Length (mm)		60	75	91	96		105	116	124	134	74	0.73
Weight (g)		2.02	4.96	9.3	10.2		13.9	18	23.2	25.4	23.38	0.23
Date placed in enclosure		6/2/2003										
Fish ID	7	Pk UP	O LP cl.									
Fork Length (mm)		61	60	65	71		77	83	86	89	29	0.33
Weight (g)		2.02	2.52	2.8	4		5.8	6.8	7	7.82	5.3	0.06
Date placed in enclosure		6/2/2003	6/17/2003									
Fish ID	8	W UP			R LP							
Fork Length (mm)		62	77	97	102		115	128	131	138	76	0.75
Weight (g)		2.27	5.63	12	12.8		19.5	25.5	29	30.61	17.81	0.18
Date placed in enclosure		6/2/2003			7/14/2003							
Fish ID	9	O UP	G nose		G nose	G nose cl.						
Fork Length (mm)		63	64	73	78	80	80	91	100	107	27	0.48
Weight (g)		2.29	2.71	4.6	5.1	5.3	5.8	7.9	11.3	12.95	7.65	0.14
Date placed in enclosure		6/2/2003	6/17/2003			7/17/2003						
Fish ID	10	G UP			G UP	P LP cl.						
Fork Length (mm)		60	74	89	94	77	80	87	96	102	25	0.45
Weight (g)		1.96	4.79	8.5	9.8	5.2	5.8	7.1	10.3	11.6	6.4	0.11
Date placed in enclosure		6/2/2003				7/17/2003						

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Eye Riffle-Enclosure E										Overall Growth	Growth per day
		6/2/2003	6/16/2003	7/1/2003	7/14/2003	7/29/2003	8/11/2003	8/26/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12	Week 14		
Fish ID	1	purple LP									
Fork Length (mm)		64	76	88	102	112	125	142	156	92	0.91
Weight (g)		2.44	5.18	8.8	14.2	19.1	26.5	40.8	50.01	47.57	0.47
Date placed in enclosure		6/2/2003									
Fish ID	2	Pink LP									
Fork Length (mm)		60	71	82	94	n/d	n/d	n/d	n/d	34	0.79
Weight (g)		1.98	4.14	6	10	n/d	n/d	n/d	n/d	8.02	0.19
Date placed in enclosure		6/2/2003									
Fish ID	3	white LP									
Fork Length (mm)		65	76	86	96	n/d	n/d	126	141	76	0.75
Weight (g)		2.52	5.34	8	11.1	n/d	n/d	23.2	30.44	27.92	0.28
Date placed in enclosure		6/2/2003									
Fish ID	4	orange LP			red LP						
Fork Length (mm)		62	75	86	97	103	106	117	126	64	0.63
Weight (g)		2.23	5.29	8	11.3	13.9	14.5	20.9	24.16	21.93	0.22
Date placed in enclosure		6/2/2003									
Fish ID	5	green LP									
Fork Length (mm)		62	74	86	100	109	119	136	153	91	0.90
Weight (g)		2.03	4.78	8.2	13.1	16.6	21.2	32.1	42.59	40.56	0.40
Date placed in enclosure		6/2/2003									

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Eye Riffle-Enclosure E										Overall Growth	Growth per day
		6/2/2003	6/16/2003	7/1/2003	7/14/2003	7/29/2003	8/11/2003	8/26/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12	Week 14		
Fish ID	6	purple UP									
Fork Length (mm)		64	78	90	105	n/d	n/d	132	141	77	0.76
Weight (g)		2.5	6.05	6.1	14.6	n/d	n/d	31.2	34.41	31.91	0.32
Date placed in enclosure		6/2/2003									
Fish ID	7	pink UP									
Fork Length (mm)		61	69	78	91	100	114	128	n/d	67	0.79
Weight (g)		1.97	3.91	6	9.5	12.1	18.1	26.6	n/d	24.63	0.29
Date placed in enclosure		6/2/2003									
Fish ID	8	white UP									
Fork Length (mm)		63	74	89	100	109	n/d	127	141	78	0.77
Weight (g)		2.36	4.73	8.2	12.2	15.2	n/d	24.1	30.32	27.96	0.28
Date placed in enclosure		6/2/2003									
Fish ID	9	orange UP									
Fork Length (mm)		63	83	97	109	122	136	143	164	101	1.00
Weight (g)		2.35	7.42	12.3	16.5	23.5	32.5	40	54.09	51.74	0.51
Date placed in enclosure		6/2/2003									
Fish ID	10	green UP									
Fork Length (mm)		60	71	84	94	107	113	n/d	n/d	53	0.76
Weight (g)		1.91	4.23	7.3	11.6	15.4	18.2	n/d	n/d	16.29	0.23

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Eye Riffle-Enclosure E										Overall Growth	Growth per day
		6/2/2003	6/16/2003	7/1/2003	7/14/2003	7/29/2003	8/11/2003	8/26/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12	Week 14		
Date placed in enclosure		6/2/2003									

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Eye Riffle-Enclosure F										Overall Growth	Growth per day
		6/2/2003	6/16/2003	7/1/2003	7/14/2003	7/29/2003	8/11/2003	8/26/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12	Week 14		
Fish ID	1	P LP			R N & LP cl						
Fork Length (mm)		60	74	78	75	82	91	97	108	33	0.56
Weight (g)		2.05	5.16	5.9	5.3	7.2	9.2	12.4	16.74	11.44	0.19
Date placed in enclosure		6/2/2003			7/14/2003						
Fish ID	2	Pk LP			G N & LP cl						
Fork Length (mm)		67	89	93	82	90	96	98	110	28	0.47
Weight (g)		2.92	9.02	9.3	6.4	8.7	10	10.9	15.68	9.28	0.16
Date placed in enclosure		6/2/2003			7/14/2003						
Fish ID	3	W LP			P N & LP cl						
Fork Length (mm)		62	75	81	84	102	120	134	152	68	1.15
Weight (g)		2.12	5.14	6.1	6.9	13	21.8	33	48.19	41.29	0.70
Date placed in enclosure		6/2/2003			7/14/2003						
Fish ID	4	O LP			Y N & LP cl						
Fork Length (mm)		60	78	84	83	94	107	116	127	44	0.75
Weight (g)		2.07	6.05	7.1	6	8.8	13.3	18.2	23.44	17.44	0.30
Date placed in enclosure		6/2/2003			7/14/2003						
Fish ID	5	G LP			B N & LP cl						
Fork Length (mm)		60	75	83	80	87	94	98	109	29	0.49
Weight (g)		1.95	4.7	6.9	5.6	7	8.1	10.3	13.8	8.2	0.14
Date placed in enclosure		6/2/2003			7/14/2003						

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Eye Riffle-Enclosure F										Overall Growth	Growth per day
		6/2/2003	6/16/2003	7/1/2003	7/14/2003	7/29/2003	8/11/2003	8/26/2003	9/11/2003		
	Fish	Week 0	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12	Week 14		
Fish ID	6	O nose, P UP			B N cl						
Fork Length (mm)		59	71	80	79	84	92	94	102	23	0.39
Weight (g)		1.81	4.34	5.9	5.4	6.3	7.7	9.7	12.19	6.79	0.12
Date placed in enclosure		6/2/2003			7/14/2003						
Fish ID	7	Pk UP			R N cl						
Fork Length (mm)		64	82	87	88	91	102	107	119	31	0.53
Weight (g)		2.29	6.45	7.5	7.4	8.6	10.6	14.5	19.4	12	0.20
Date placed in enclosure		6/2/2003			7/14/2003						
Fish ID	8	W UP			G N cl						
Fork Length (mm)		66	87	98	91	100	115	125	138	47	0.80
Weight (g)		2.75	8.58	11.2	7.7	11.2	16.7	21.9	29.66	21.96	0.37
Date placed in enclosure		6/2/2003			7/14/2003						
Fish ID	9	O UP			P N cl						
Fork Length (mm)		68	89	104	90	93	103	104	128	38	0.64
Weight (g)		2.81	9.55	13.8	8.4	9.5	11.9	18.5	25.03	16.63	0.28
Date placed in enclosure		6/2/2003			7/17/2003						
Fish ID	10	G UP			Y N cl						
Fork Length (mm)		60	74	82	79	82	89	94	102	23	0.39
Weight (g)		1.9	5.17	6.6	5.3	6.2	7.4	9.4	12.21	6.91	0.12
Date placed in enclosure		6/2/2003			7/14/2003						

Preliminary Information – Subject to Revision – For Collaborative Process Purposes Only

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Oroville Facilities Relicensing Team

March 23, 2004

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